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MEMO

To: Jack Garman
From: Larry Berman
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Subject: Idiosyncracies of the Ascent Guidance

1. Cross Range - The cross range displayed in Noun 76 is the size of the lateral maneuver which the guidance intends to make during ascent. It is not the distance out of plane of the injection point. The initial Noun 76 display is based on coplanar injection, that is the guidance intends to remove all the out-of-plane. If the crew overrides this value via the keyboard, a noncoplanar insertion will result.

2. FDAI Angles - The pitch angle displayed in Noun 74 should be approximately -50° (equivalent to 310° on the ball). A display which is significantly different indicates some problem. The yaw angle should be approximately 1.4° for each nautical mile of the cross range maneuver (see 1 above).

3. Vgx Display - During the vertical rise portion of the flight, Vgx in Noun 94 will display something like +900.0 fps. This is because the $\underline{V}g$ includes compensation for the expected ΔV due to gravity, and during vertical rise this is all along the X axis. At pitchover, this should increase to about 4800.0 fps.

4. Tgo Computation in RCS Mode - The Tgo computation during RCS uses an assumed acceleration of a dry LM with 4 RCS jets on. This tends to yield an underestimate of Tgo. However, in RCS mode neither Noun 77 nor the downlink ever receive Tgo, their values remain as they were when RCS mode was entered.

5. Insertion Altitude - Because of non-linearities in the physical problem, the guidance constants A and B in the computed radial acceleration,

$$A_{TR} = \frac{1}{\tau}(A + B\,\Delta t) - g_{eff},$$

drift during the flight. The value of B is limited to: $-.1\tau \leq B \leq 0$. In most flights, B bumps against the upper limit some time before insertion, and we lose altitude control. In a nominal ascent this happens about 100 sec before insertion and causes an overshoot of about 400 ft. The worst case is that of a DPS abort followed by APS to insertion. With the DPS burning, the high acceleration yields a short Tgo. With staging, Tgo doubles (approximately), and the guidance requires a large negative A and positive B to kill off radial rate quickly and prevent overshoot. These are not permitted, and the resulting cutoff altitude can be as high as 75000 ft. (Note that the variable targeting for aborts still provides the correct insertion speed.)

6. Drift of $\underline{V}g$ after Insertion - The radial velocity target and the down-range target in the case of P12 are fixed. Therefore, when the vehicle is in a non-circular orbit and its actual radial and tangential speeds vary after insertion, the residuals ($\underline{V}g$) displayed in N85 will change. The horizontal drift is mainly a function of radial rate and for nominal insertion it is .031 ft/sec^2. (For aborts, there is no drift.) The radial drift is mainly a function of insertion speed. It varies essentially linearly from .045 ft/sec^2 for V = 5500 fps to .315 ft/sec^2 for V = 5640 fps. The numbers quoted are the changes in the actual vehicle rates. For body X-axis horizontal and wings level, they will be Vgx and Vgz respectively.

7. Rotation Control Anomalies - The rotation control logic built into the guidance for abort situations will work in all reasonable situations. However it is possible to get into conditions where rotation through the downward vertical happens. Consider, for example, a very early abort in which a manual pitch maneuver over-the-top is made giving a significant (upward) radial rate, and an over speed down range rate. If Tgo<10 when P70/71 is entered, the desired thrust vector, with

position control off, will be downward and retrograde. If the vehicle X-axis is within 30^o of +R, rotation control is off, and if the angles work out right the vehicle could pitch forward through the downward vertical.

Other possibilities could be outlined, but it should be pointed out that they all require very unusual combinations of state vector and vehicle attitude. Pitch through the downward vertical is not impossible, just highly unlikely.

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